# Coupling long-term prospection data and remote-sensing vegetation index to help in the preventative control of Desert Locust

Cyril Piou

Ahmed Salem Benahi, Vincent Bonal, Mohamed el Hacen Jaavar, Valentine Lebourgeois, Michel Lecoq, Jean-Michel Vassal





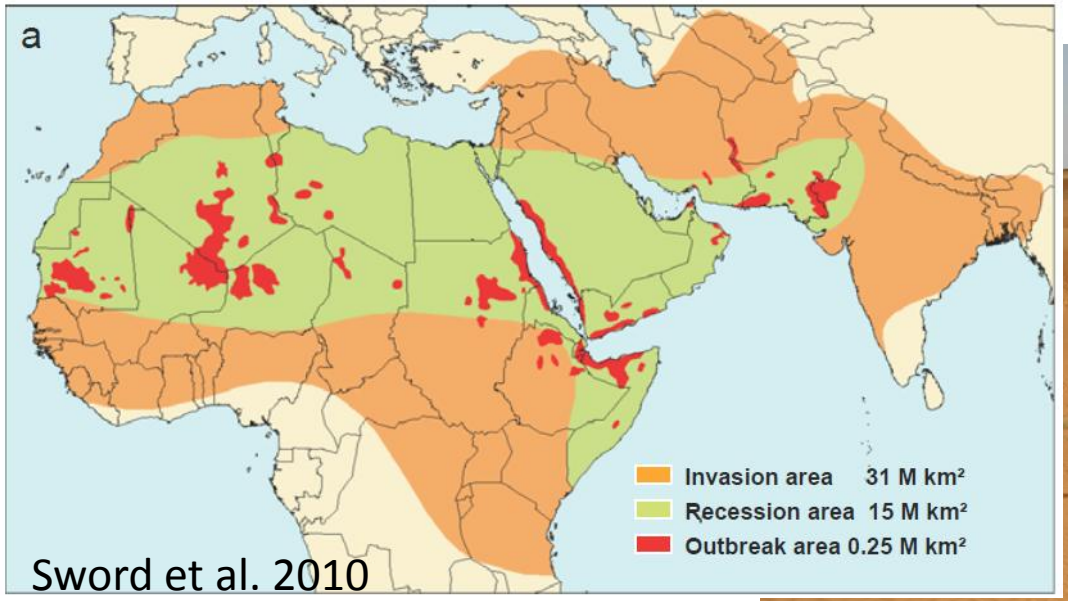
# Introduction

- *Schistocerca gregaria*: major locust species


Gregarization

# Introduction

- *Schistocerca gregaria*: major locust species
- Preventative management since 1960's
- Large distribution area: Where to survey?

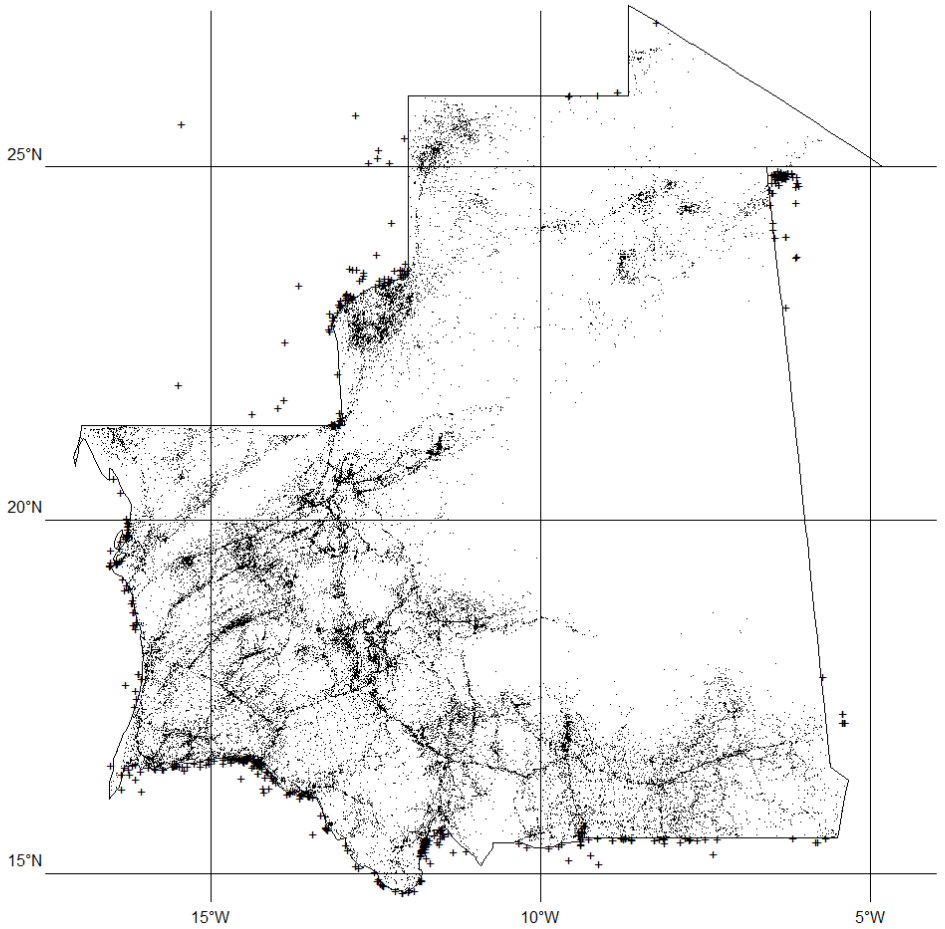



Sword et al. 2010

*Photo : A. Foucart*

# Introduction

- Prospection data in Mauritania since 1988
- Bias of prospection:
  - Target oriented
  - Accessibility
- Used to characterize habitats (e.g. Babah 2008)
- But never directly used in combination with satellites data



# Introduction

- Remote sensing has long been discuss as a help to focus surveys:
  - Development of ARTEMIS by FAO based on Meteosat and NOAA-AVHRR satellite data from 1975 (Tucker et al. 1985, Hielkema 1990)
  - Number of pixels with NDVI > 0.09 or 0.13 (at 7.4km resolution) explained locust presence in Red Sea area during 1980's-1990's (Despland et al. 2004)
  - But Tratalos et al. (2006) demonstrated that GAC-NDVI does not explain overall locust presence (at 8km resolution)
- One major recent advances (since 2000) is the higher resolution of MODIS – NDVI (250m resolution) + free access
  - MODIS images used in FAO's early warning system (Cressman & Hodson 2009)

# Introduction

- Objectives:
  - Identify information from vegetation structure(s) able to explain desert locust presence
  - Integrate these information on early warning system ➔ reduce the prospection area

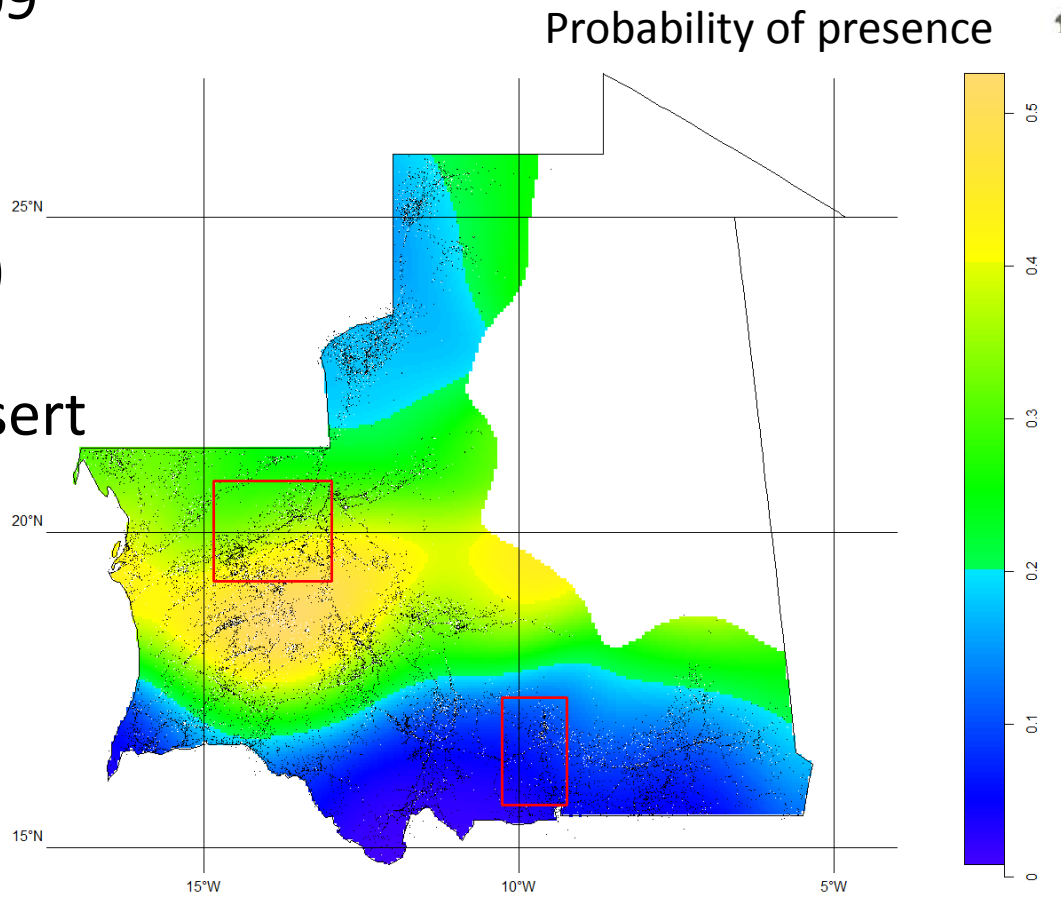
# Methods

- MODIS from 2000
- Invasion period 2003-2004

➔Focus on 2005 – 2009 period

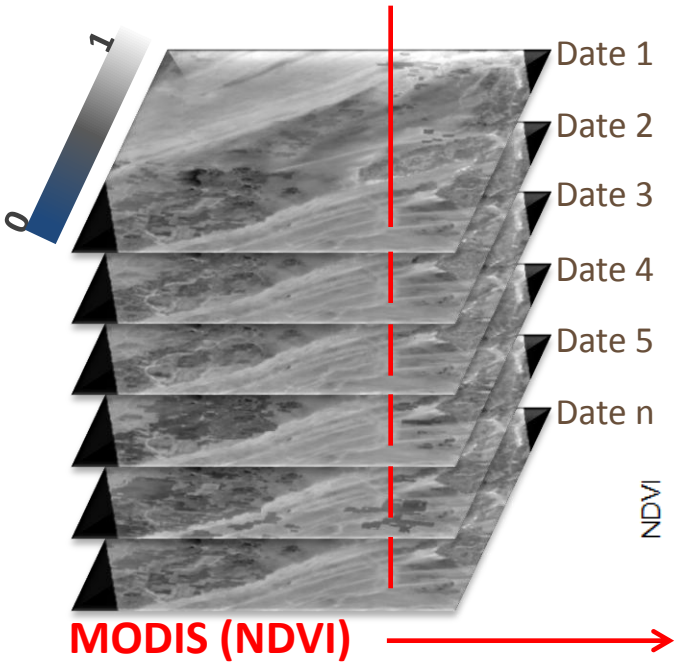
➔Focus on 2 working areas (representativeness)

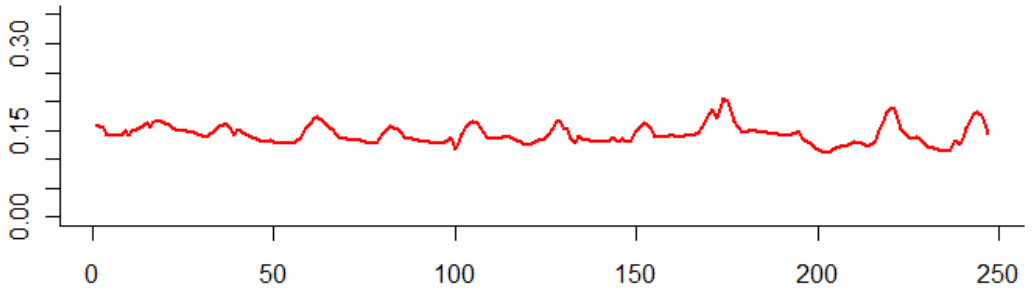
➔1769 points, 11% presence of desert locust



# Methods

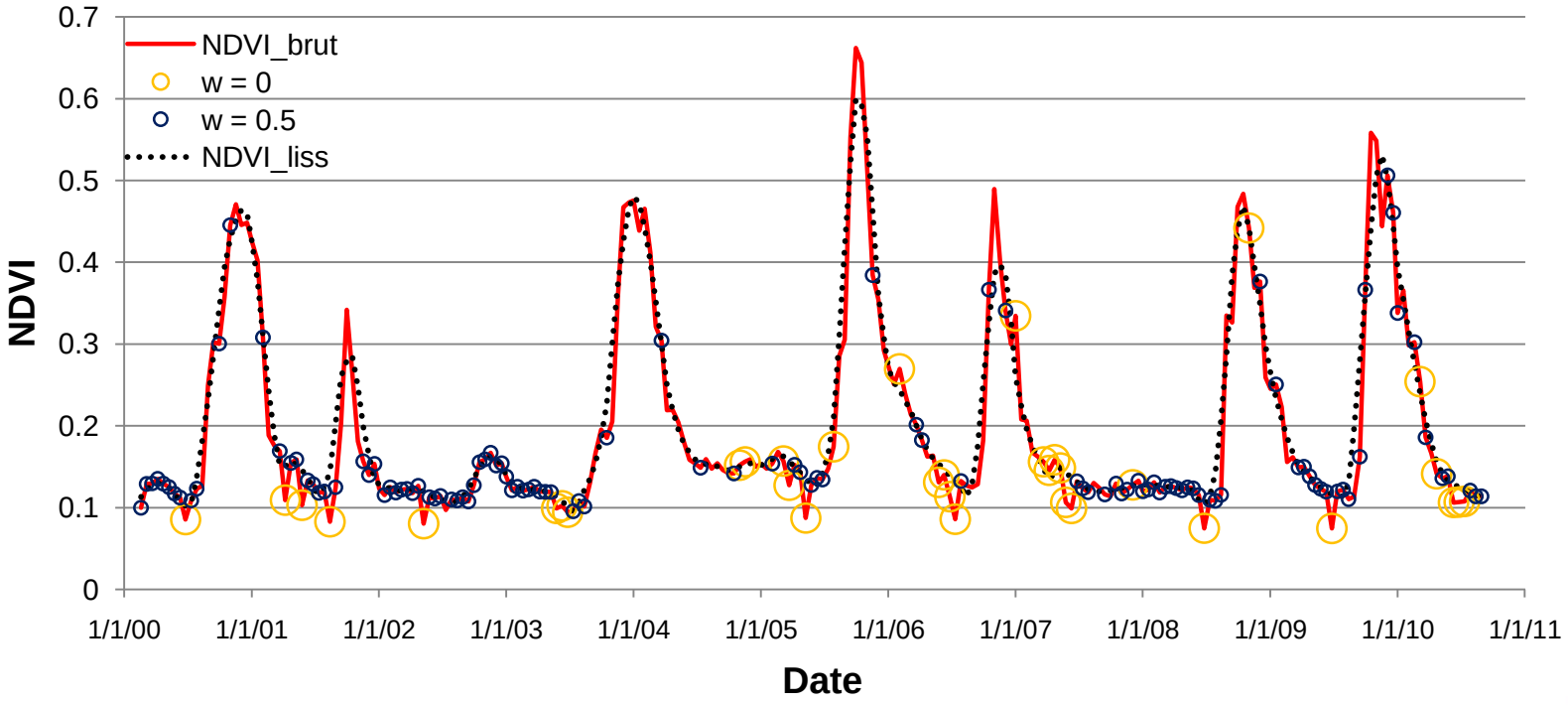
- NDVI data → every 16 days composite from MODIS satellites



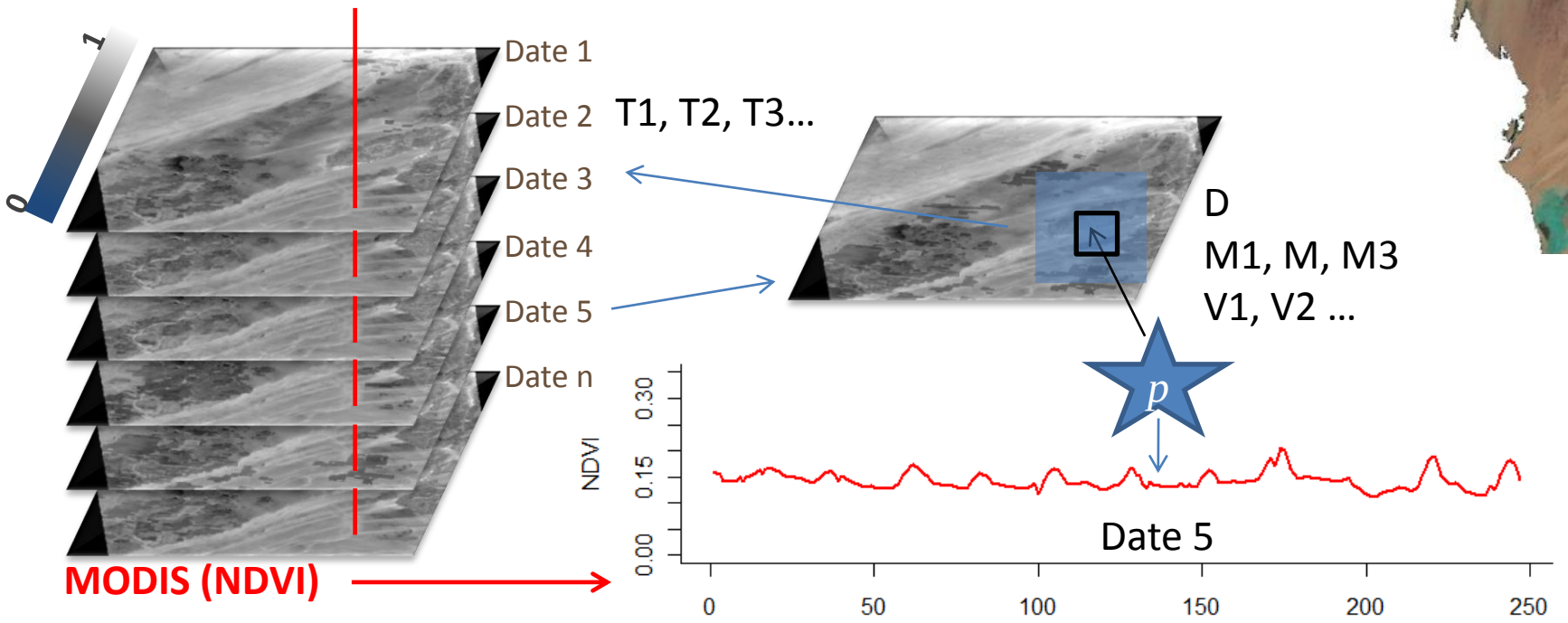
# Methods

- Smoothing of time series:
  - First statistics to summarize these series:
    - minimum, maximum



# Methods

- For each prospection point $p$, transformation of NDVI at $t$:
  - $V$ = Proportion of vegetated pixels over 65x65 around $p$
  - $M$ = Mean NDVI over 5x5 pixels around $p$
  - $T$ = Proportion of change of $M$ between $t$-2 and $t$-3
  - $D$ = "Fractal Dimension" over 65x65 area (Despland et al. 2004)



# Methods

- Logistic regression:

From: $\text{Logit}\left[\Pr\left(p = presence\right)\right] = \alpha_0 + \alpha_1 \cdot X$

To:

$$\text{Logit}\left[\Pr\left(p = presence\right)\right] = \alpha_0 + \alpha_1 \cdot T + \alpha_2 \cdot T^2 + \alpha_3 \cdot M + \alpha_4 \cdot M^2 + \alpha_5 \cdot V + \alpha_6 \cdot V^2 + \alpha_7 \cdot D + \alpha_8 \cdot D^2 + \alpha_9 \cdot maxNDVI + \alpha_{10} \cdot maxNDVI^2 + \alpha_{11} \cdot minNDVI + \alpha_{12} \cdot minNDVI^2$$

Temporal

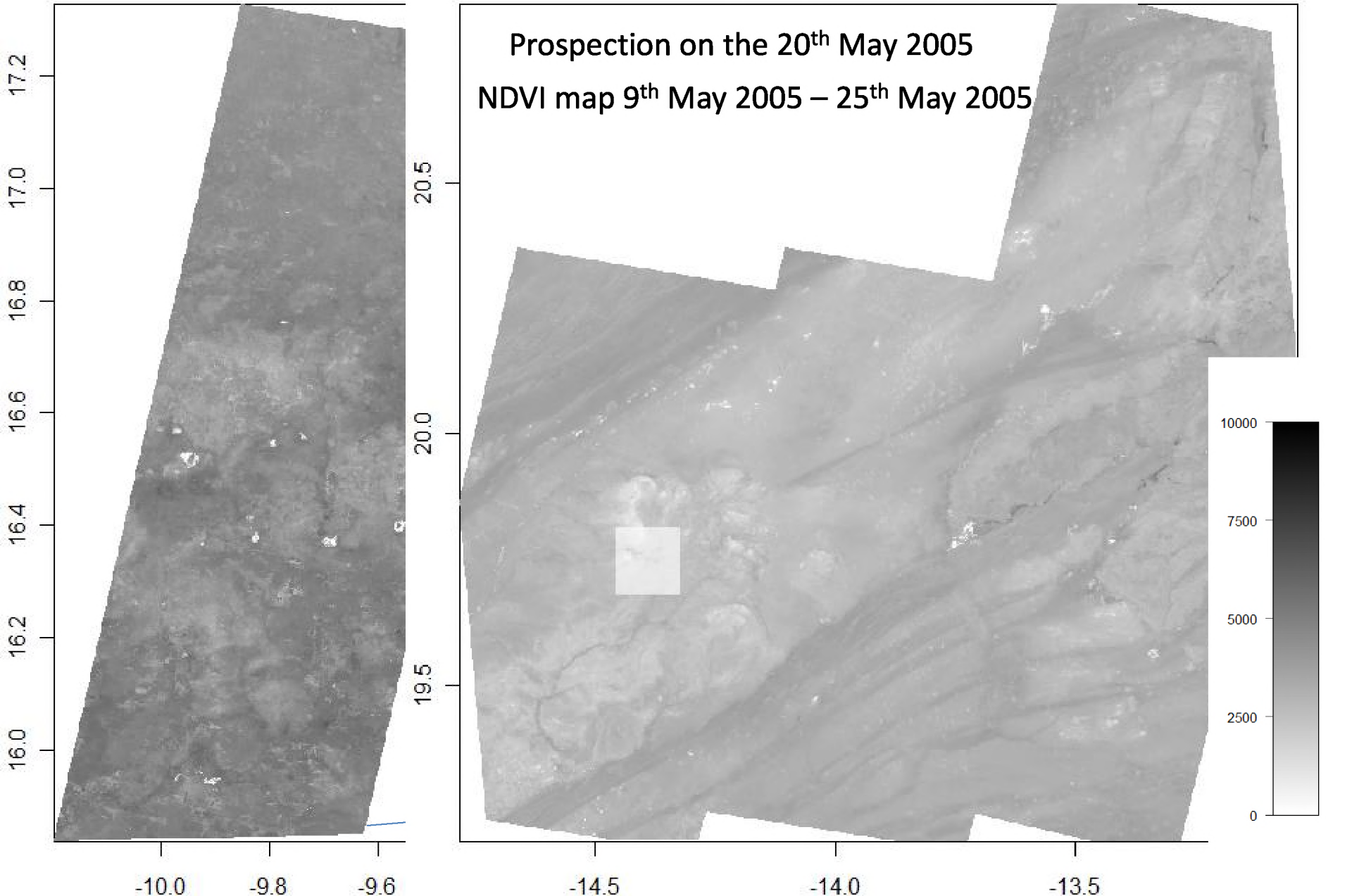
Local

Structural

Static

➔Stepwise selection of variables

➔AIC scores


Prospection on the 20th May 2005
NDVI map 9th May 2005 – 25th May 2005
17.2
17.0
16.8
16.6
16.4
16.2
16.0
-10.0
-9.8
-9.6
20.5
20.0
19.5
-14.5
-14.0
-13.5
10000
7500
5000
2500
0

# Results

- Multi-model inference:
  - 8 Best models of 78 possible…

Best

| MODELS | AIC |
|---|---|
| $maxNDVI + maxNDVI^2 + minNDVI^2 + D + D^2 + V + M + M^2 + T + T^2$ | 938.6855 |
| $maxNDVI + minNDVI^2 + D + D^2 + V + M + T + T^2$ | 941.2438 |
| $maxNDVI + maxNDVI^2 + minNDVI + D + D^2 + V + M + M^2 + T + T^2$ | 941.3720 |
| $maxNDVI + minNDVI + D + D^2 + V + M + T + T^2$ | 943.8539 |
| $maxNDVI + maxNDVI^2 + minNDVI^2 + D + V + V^2 + M + M^2 + T + T^2$ | 944.2404 |
| $maxNDVI + minNDVI^2 + D + V + M + T + T^2$ | 945.0244 |
| $maxNDVI + maxNDVI^2 + minNDVI^2 + D + V + M + M^2 + T + T^2$ | 945.0261 |
| $maxNDVI + maxNDVI^2 + minNDVI + D + V + V^2 + M + M^2 + T + T^2$ | 947.4694 |

Worse

Static variables

Structural

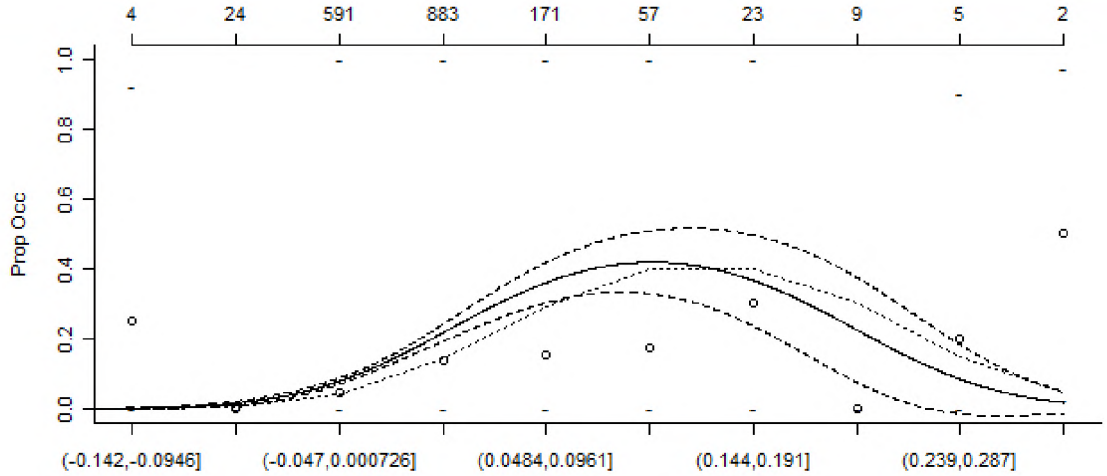
Local

Temporal

Dynamic variables

# Results

| | Estimate | Std. Error | Z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | 9,98E+00 | 7,63E+00 | 1,308 | 0,19098 |
| *maxNDVI* | -2,10E-03 | 6,94E-04 | -3,021 | 0,00252 ** |
| *maxNDVI²* | 2,59E-07 | 1,18E-07 | 2,196 | 0,02807 * |
| *minNDVI²* | 2,86E-06 | 4,28E-07 | 6,684 | 2,33E-11 *** |
| *D* | -3,42E+01 | 1,32E+01 | -2,587 | 0,00968 ** |
| *D²* | 1,62E+01 | 5,49E+00 | 2,948 | 0,0032 ** |
| *V* | -2,54E+01 | 4,32E+00 | -5,888 | 3,91E-09 *** |
| *M* | 6,48E-03 | 1,62E-03 | 4,01 | 6,06E-05 *** |
| *M²* | -8,58E-07 | 3,76E-07 | -2,281 | 0,02256 * |
| *T* | 2,98E+01 | 4,60E+00 | 6,477 | 9,33E-11 *** |
| *T²* | -1,03E+02 | 2,43E+01 | -4,226 | 2,38E-05 *** |



# Discussion

- First results show:
  - Importance of temporal changes (with intermediary speed of increase in vegetation)
  - Potential of explanation of local NDVI value
  - Implication of large scale vegetation (high fractal dimension + low coverage → higher presence)
  - Possibility to use the static maps of NDVI statistics as background habitat influence

# Discussion

- Perspectives:
  - Larger area of analysis
  - Verify extrapolations
  - Hierarchical Bayesian and State-Space models:
    - Simulating prospection choices
    - Phase change from prospection data (presence solitarious → presence of gregarious)
  - Integration of simplified version of this kind of model in RAMSES-GIS of FAO for early identification of critical areas

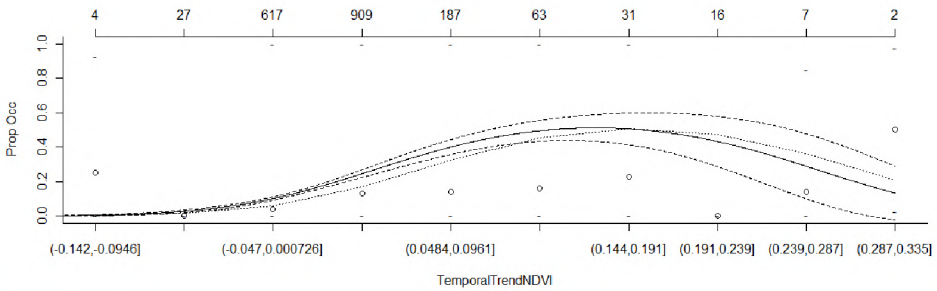
# Take home messages

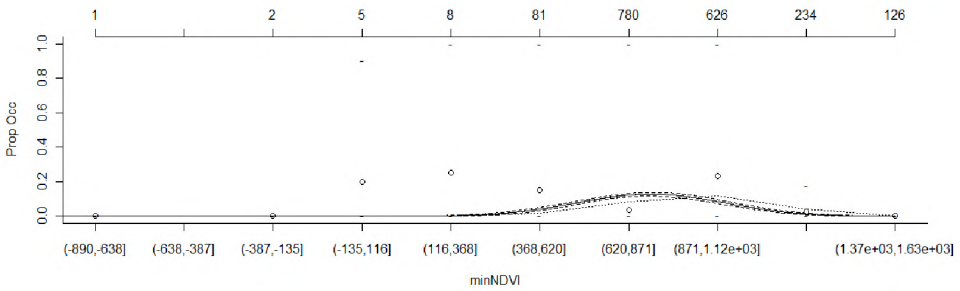
- Presence of locust appear clearly linked to vegetation index (vs. Tratalos et al. 2006)
- Long term data sets of prospection should not be left sleeping on shelves…

# Thank you …
# Merci de votre attention

# Supplementary

- Model for GIS integration:




$$\text{Logit}\left[\Pr\left(p = presence\right)\right] = \alpha_0 + \alpha_1 \cdot T + \alpha_2 \cdot T^2 + \alpha_3 \cdot minNDVI + \alpha_4 \cdot minNDVI^2$$

| | Estimate | Std. Error | z value | Pr(>\|z\|) | |
|---|---|---|---|---|---|
| (Intercept) (α) | -1,32E+01 | 1,88E+00 | -7,041 | 1,92E-12 | *** |
| minNDVI (α3) | 2,37E-02 | 3,87E-03 | 6,138 | 8,37E-10 | *** |
| minNDVI2 (α4) | -1,27E-05 | 1,97E-06 | -6,459 | 1,05E-10 | *** |
| TemporalTrendNDVI (α1) | 2,59E+01 | 3,64E+00 | 7,102 | 1,23E-12 | *** |
| TemporalTrendNDVI2 (α2) | -7,45E+01 | 1,98E+01 | -3,759 | 0,000171 | *** |

# Results

| | Estimate | Std. Error | Z value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | 9,98E+00 | 7,63E+00 | 1,308 | 0,19098 |
| *maxNDVI* | -2,10E-03 | 6,94E-04 | -3,021 | 0,00252 ** |
| *maxNDVI²* | 2,59E-07 | 1,18E-07 | 2,196 | 0,02807 * |
| *minNDVI²* | 2,86E-06 | 4,28E-07 | 6,684 | 2,33E-11 *** |
| *D* | -3,42E+01 | 1,32E+01 | -2,587 | 0,00968 ** |
| *D²* | 1,62E+01 | 5,49E+00 | 2,948 | 0,0032 ** |
| *V* | -2,54E+01 | 4,32E+00 | -5,888 | 3,91E-09 *** |
| *M* | 6,48E-03 | 1,62E-03 | 4,01 | 6,06E-05 *** |
| *M²* | -8,58E-07 | 3,76E-07 | -2,281 | 0,02256 * |
| *T* | 2,98E+01 | 4,60E+00 | 6,477 | 9,33E-11 *** |
| *T²* | -1,03E+02 | 2,43E+01 | -4,226 | 2,38E-05 *** |